Claims

The invention claimed is:

1. An arrayed in-line optical device, comprising:

a first optical fiber collimator array, including:

a first optical fiber array block configured to receive and retain a first plurality of individual optical fibers which carry optical signals, the first optical fiber array block including a first block surface; and

a first microlens array substrate coupled to the first optical fiber array block, the first microlens array substrate including a first plurality of microlenses integrated along a first microlens surface and a first substrate surface opposite the first microlens surface, wherein the optical signals from the first plurality of individual optical fibers are each collimated by a different one of the first plurality of integrated microlenses;

a second optical fiber collimator array, including:

a second optical fiber array block configured to receive and retain a second plurality of individual optical fibers which carry the optical signals, the second optical fiber array block including a second block surface; and

a second microlens array substrate coupled to the second optical fiber array block, the second microlens array substrate including a second plurality of microlenses integrated along a second microlens surface and a second substrate surface opposite the second microlens surface, wherein the optical signals provided to the second plurality of individual optical fibers are each provided by a different one of the second plurality of integrated microlenses; and

an optical chip coupled between the first microlens array substrate and the second microlens array substrate, the optical chip including a first chip surface and a second chip surface.

2. The arrayed optical device of claim 1, wherein the first and second optical fiber array blocks and the first and second microlens array substrates are made of materials with substantially similar coefficients of thermal expansion (CTE).

3. The arrayed optical device of claim 1, wherein the first substrate surface is coupled to the first block surface and the second substrate surface is coupled to the second block surface, and wherein the optical chip is coupled between the first microlens surface of the first microlens array substrate and the second microlens surface of the second microlens array substrate.

4. The arrayed optical device of claim 3, wherein the first plurality of individual optical fibers are symmetrically positioned in a coupled surface formed by the first block surface and the first substrate surface, and wherein the second plurality of individual optical fibers are symmetrically positioned in a coupled surface formed by the second block surface and the second substrate surface.

5. The arrayed optical device of claim 3, wherein the first and second block surfaces are angled and the first and second substrate surfaces are sloped.

6. The arrayed optical device of claim 5, wherein lens axes of the first and second plurality of integrated microlenses are tilted to the optical axis that passes through the first and second plurality of integrated microlenses at an angle in the range of about 0.1 to 10 degrees.

7. The arrayed optical device of claim 5, wherein the optical chip is slanted against the optical axis and the first and second chip surfaces are at an angle in the range of about 0.1 to 10 degrees from perpendicular to the optical axis of the optical powers that pass through the optical chip.

8. The arrayed optical device of claim 1, wherein the first and second plurality of integrated microlenses are one of graded-index (GRIN) lenses, diffractive lenses and refractive lenses.

9. The arrayed optical device of claim 3, wherein the first substrate surface is coupled to the first block surface by an index-matched optical adhesive, and wherein the second substrate surface is coupled to the second block surface by another index-matched optical adhesive.

10. The arrayed optical device of claim 7, further including:

a spacer configured to retain the optical chip and provide an air gap between the first chip surface and the first plurality of microlenses and another air gap between the second chip surface and the second plurality of microlenses.

11. The arrayed optical device of claim 7, wherein the first chip surface of the optical chip is coupled to the first microlens surface of the first microlens array substrate and the second chip surface of the optical chip is coupled to the second microlens surface of the second microlens array substrate, and wherein the first microlens array substrate is configured to provide an air gap between the first chip surface and the first plurality of microlenses and the second microlens array substrate is configured to provide another air gap between the second chip surface and the second plurality of microlenses.

12. The arrayed optical device of claim 3, wherein one of the first microlens surface and the first chip surface includes an anti-reflection (AR) coating and one of the second microlens surface and the second chip surface includes an anti-reflection (AR) coating, and wherein the first microlens surface is coupled to the first chip surface by an index-matched optical adhesive and the second microlens surface is coupled to the second chip surface by another index-matched optical adhesive.

13. The arrayed optical device of claim 9, wherein one of the first block surface and the first substrate surface includes an anti-reflection (AR) coating, and wherein one of the second block surface and the second substrate surface includes an anti-reflection (AR) coating.

14. The arrayed optical device of claim 1, wherein the pitch of the first and second plurality of integrated microlenses is about 250 microns.

15. The arrayed optical device of claim 1, wherein the pitch of the first and second plurality of integrated microlenses is within a range of about 125 to 2500 microns.

16. The arrayed optical device of claim 5, wherein the slope of the first and second substrate surfaces and the angle of the first and second block surfaces are in a range of about 2 to 20 degrees from perpendicular to the optical axes of the first and second plurality of individual optical fibers, respectively.

17. The arrayed optical device of claim 1, wherein the optical chip includes at least one of an optical isolator chip, an optical circulator chip, a gain flattening filter, a thin film filter, a variable optical attenuator, a polarization beam splitter, a wavelength plate, a prism, a grating, a mirror, a dynamically adjustable active optical material and a polarizing material.

18. The arrayed optical device of claim 17, wherein the optical isolator chip is a stacked optical isolator chip that includes first and second birefringent crystal plates, a half-wave plate and one of a latching garnet and a non-latching garnet.

19. The arrayed optical device of claim 1, further including:

a first spacer, the first spacer coupling the first optical fiber array block to the first microlens array substrate; and

a second spacer, the second spacer coupling the second optical fiber array block to the second microlens array substrate.

20. The arrayed optical device of claim 19, wherein the first and second optical fiber array blocks, the first and second microlens array substrates and the first and second spacers are made of materials with substantially similar coefficients of thermal expansion (CTE).

21. The arrayed optical device of claim 19, wherein the first spacer includes a first front surface and a first back surface opposite the first front surface and the second spacer includes a second front surface and a second back surface opposite the second front surface, and wherein the first plurality of individual optical fibers are symmetrically positioned in a coupled surface formed by the first block surface and the first front surface and the second plurality of individual optical fibers are symmetrically positioned in a coupled surface formed by the second block surface and the second front surface, where the first plurality of microlenses are symmetrically positioned in a coupled surface formed by the first back surface and the first microlens array substrate and the second plurality of microlenses are symmetrically positioned in a coupled surface formed by the second back surface and the second microlens array substrate.

22. The arrayed optical device of claim 19, wherein a refractive index of the first spacer is substantially similar to a refractive index of a core of each of the first plurality of individual optical fibers and a refractive index of the second spacer is substantially similar to a refractive index of a core of each of the second plurality of individual optical fibers.

23. The arrayed optical device of claim 19, wherein a refractive index of the first spacer is substantially similar to a refractive index of each of the first plurality of microlenses and a refractive index of the second spacer is substantially similar to a refractive index of each of the second plurality of microlenses.

24. The arrayed optical device of claim 19, wherein the first substrate surface is sloped and is coupled to the first chip surface and the second substrate surface is sloped and is coupled to the second chip surface, and wherein the first and second substrate surfaces are at an angle in the range of about 0.1 to 10 degrees from perpendicular to the optical axis of the optical powers that pass through the optical chip.

25. The arrayed optical device of claim 24, wherein the first block surface is angled and the first spacer includes a first slanted surface and a first back surface opposite the first slanted surface and the second block surface is angled and the second spacer includes a second slanted surface and a second back surface opposite the second slanted surface, and wherein the first slanted surface is coupled to the first block surface and the first back surface is coupled to the first microlens surface and the second slanted surface is coupled to the second block surface and the second back surface is coupled to the second microlens surface.

26. The arrayed optical device of claim 25, wherein the first spacer includes a first hole such that the optical signals provided by the first plurality of individual optical fibers pass only through air before encountering one of the first plurality of microlenses, and wherein the second spacer includes a second hole such that the optical signals provided to the second plurality of individual optical fibers pass only through air after encountering one of the second plurality of microlenses.

27. The arrayed optical device of claim 19, wherein the first block surface is angled and the first spacer includes a first slanted surface and a first back surface opposite the first slanted surface and the second block surface is angled and the second spacer includes a second slanted surface and a second back surface opposite the second slanted surface, and wherein the first slanted surface is coupled to the first block surface and the first back surface is coupled to the first substrate surface and the second slanted surface is coupled to the second block surface and the second back surface is coupled to the second substrate surface, where the angle of the first and second block surfaces are in a range of about 2 to 20 degrees from perpendicular to the optical axes of the first and second plurality of individual optical fibers, respectively, and where lens axes of

the first and second microlenses are tilted to the optical axes that pass through the first and second microlenses at an angle in the range of about 0.1 to 10 degrees.

28. The arrayed optical device of claim 27, where the first spacer includes a first hole such that the optical signals provided by the first plurality of individual optical fibers pass only through air before encountering the first microlens array substrate, and where the second spacer includes a second hole such that the optical signals provided to the second plurality of individual optical fibers pass only through air after encountering the second microlens array substrate.

29. The arrayed optical device of claim 19, wherein the first and second plurality of integrated microlenses are one of graded index (GRIN) lenses, refractive lenses and diffractive lenses.

30. The arrayed optical device of claim 19, further including:

a first index-matched chip spacer for coupling the first microlens array substrate to the optical chip, the first index-matched chip spacer having a refractive index similar to that of the first substrate and including a first inclined surface that is coupled to the first chip surface and a first perpendicular surface opposite the first inclined surface that is coupled to the first microlens array substrate, the first inclined surface having an angle in the range of about 0.1 to 10 degrees from perpendicular to the optical axis of the optical powers that pass through the optical chip; and

a second index-matched chip spacer for coupling the second microlens array substrate to the optical chip, the second index-matched chip spacer having a refractive index similar to that of the second substrate and including a second inclined surface that is coupled to the second chip surface and a second perpendicular surface opposite the second inclined surface that is coupled to the second microlens array substrate, the second inclined surface having an angle in the range of about 0.1 to 10 degrees from perpendicular to the optical axis of the optical powers that pass through the optical chip.

31. The arrayed optical device of claim 25, wherein the first spacer is an index-matched spacer that is coupled to the first optical fiber array block and the first microlens array substrate by an index-matched optical adhesive, and wherein the second spacer is an index-matched spacer that is coupled to the second optical fiber array block and the second microlens array substrate by another index-matched optical adhesive.

32. The arrayed optical device of claim 19, wherein the pitch of the first and second plurality of integrated microlenses is about 250 microns.

33. The arrayed optical device of claim 19, wherein the pitch of the first and second plurality of integrated microlenses is within a range of about 125 to 2500 microns.

34. The arrayed optical device of claim 25, wherein the first slanted surface of the first spacer and the first block surface of the first optical fiber array block are in a range of about 2 to 20 degrees from perpendicular to the optical axes of the first plurality of individual optical fibers, and wherein the second slanted surface of the second spacer and the second block surface of the second optical fiber array block are in a range of about 2 to 20 degrees from perpendicular to the optical axes of the second plurality of individual optical fibers.

35. The arrayed optical device of claim 19, wherein the optical chip includes at least one of an optical isolator chip, an optical circulator chip, a gain flattening filter, a thin film filter, a variable optical attenuator, a polarization beam splitter, a wavelength plate, a prism, a grating, a mirror, a dynamically adjustable active optical material and a polarizing material.

36. The arrayed optical device of claim 35, wherein the optical isolator chip is a stacked optical isolator chip that includes first and second birefringent crystal plates, a half-wave plate and one of a latching garnet and a non-latching garnet.

37. A method for providing an arrayed optical device, comprising:

providing a first optical fiber array block configured to receive and retain a first plurality of individual optical fibers which carry optical signals, the first optical fiber array block including a first block surface;

providing a first microlens array substrate coupled to the first optical fiber array block, the first microlens array substrate including a first plurality of microlenses integrated along a first microlens surface and a first substrate surface opposite the first microlens surface, wherein the optical signals from the first plurality of individual optical fibers are each collimated by a different one of the first plurality of integrated microlenses;

providing a second optical fiber array block configured to receive and retain a second plurality of individual optical fibers which carry the optical signals, the second optical fiber array block including a second block surface;

providing a second microlens array substrate coupled to the second optical fiber array block, the second microlens array substrate including a second plurality of microlenses integrated along a second microlens surface and a second substrate surface opposite the second microlens surface, wherein the optical signals provided to the second plurality of individual optical fibers are each provided by a different one of the second plurality of integrated microlenses; and

providing an optical chip coupled between the first microlens array substrate and the second microlens array substrate, the optical chip including a first chip surface and a second chip surface.

38. The method of claim 37, wherein the first and second optical fiber array blocks and the first and second microlens array substrates are made of materials with substantially similar coefficients of thermal expansion (CTE).

39. The method of claim 37, wherein the first substrate surface is coupled to the first block surface and the second substrate surface is coupled to the second block surface, and wherein the optical chip is coupled between the first microlens surface of the first microlens array substrate and the second microlens surface of the second microlens array substrate.

40. The method of claim 39, wherein the first plurality of individual optical fibers are symmetrically positioned in a coupled surface formed by the first block surface and the first substrate surface, and wherein the second plurality of individual optical fibers are symmetrically positioned in a coupled surface formed by the second block surface and the second substrate surface.

41. The method of claim 39, wherein the first and second block surfaces are angled and the first and second substrate surfaces are sloped.

42. The method of claim 41, wherein lens axes of the first and second plurality of integrated microlenses are tilted to the optical axis that passes through the first and second plurality of integrated microlenses at an angle in the range of about 0.1 to 10 degrees.

43. The method of claim 41, wherein the optical chip is slanted against the optical axis and the first and second chip surfaces are at an angle in the range of about 0.1 to 10 degrees from perpendicular to the optical axis of the optical powers that pass through the optical chip.

44. The method of claim 37, wherein the first and second plurality of integrated microlenses are one of graded-index (GRIN) lenses, diffractive lenses and refractive lenses.

45. The method of claim 39, wherein the first substrate surface is coupled to the first block surface by an index-matched optical adhesive, and wherein the second substrate surface is coupled to the second block surface by another index-matched optical adhesive.

46. The method of claim 43, further including the step of:

providing a spacer configured to retain the optical chip and provide an air gap between the first chip surface and the first plurality of microlenses and another air gap between the second chip surface and the second plurality of microlenses.

47. The method of claim 43, wherein the first chip surface of the optical chip is coupled to the first microlens surface of the first microlens array substrate and the second chip surface of the optical chip is coupled to the second microlens surface of the second microlens array substrate, and wherein the first microlens array substrate is configured to provide an air gap between the first chip surface and the first plurality of microlenses and the second microlens array substrate is configured to provide another air gap between the second chip surface and the second plurality of microlenses.

48. The method of claim 39, wherein one of the first microlens surface and the first chip surface includes an anti-reflection (AR) coating and one of the second microlens surface and the second chip surface includes an anti-reflection (AR) coating, and wherein the first microlens surface is coupled to the first chip surface by an index-matched optical adhesive and the second microlens surface is coupled to the second chip surface by another index-matched optical adhesive.

49. The method of claim 45, wherein one of the first block surface and the first substrate surface includes an anti-reflection (AR) coating, and wherein one of the second block surface and the second substrate surface includes an anti-reflection (AR) coating.

50. The method of claim 37, wherein the pitch of the first and second plurality of integrated microlenses is about 250 microns.

51. The method of claim 37, wherein the pitch of the first and second plurality of integrated microlenses is within a range of about 125 to 2500 microns.

52. The method of claim 41, wherein the slope of the first and second substrate surfaces and the angle of the first and second block surfaces are in a range of about 2 to 20 degrees from perpendicular to the optical axes of the first and second plurality of individual optical fibers, respectively.

53. The method of claim 37, wherein the optical chip includes at least one of an optical isolator chip, an optical circulator chip, a gain flattening filter, a thin film filter, a variable optical attenuator, a polarization beam splitter, a wavelength plate, a prism, a grating, a mirror, a dynamically adjustable active optical material and a polarizing material.

54. The method of claim 53, wherein the optical isolator chip is a stacked optical isolator chip that includes first and second birefringent crystal plates, a half-wave plate and one of a latching garnet and a non-latching garnet.

55. The method of claim 37, further including the steps of:

providing a first spacer, the first spacer coupling the first optical fiber array block to the first microlens array substrate; and

providing a second spacer, the second spacer coupling the second optical fiber array block to the second microlens array substrate.

56. The method of claim 55, wherein the first and second optical fiber array blocks, the first and second microlens array substrates and the first and second spacers are made of materials with substantially similar coefficients of thermal expansion (CTE).

57. The method of claim 55, wherein the first spacer includes a first front surface and a first back surface opposite the first front surface and the second spacer includes a second front surface and a second back surface opposite the second front surface, and wherein the first plurality of individual optical fibers are symmetrically positioned in a coupled surface formed by the first block surface and the first front surface and the second plurality of individual optical fibers are symmetrically positioned in a coupled surface formed by the second block surface and the second front surface, where the first plurality of microlenses are symmetrically positioned in a coupled surface formed by the first back surface and the first microlens array substrate and the second plurality of microlenses are symmetrically positioned in a coupled surface formed by the second back surface and the second microlens array substrate.

58. The method of claim 55, wherein a refractive index of the first spacer is substantially similar to a refractive index of a core of each of the first plurality of individual optical fibers and a refractive index of the second spacer is substantially similar to a refractive index of a core of each of the second plurality of individual optical fibers.

59. The method of claim 55, wherein a refractive index of the first spacer is substantially similar to a refractive index of each of the first plurality of microlenses and a refractive index of the second spacer is substantially similar to a refractive index of each of the second plurality of microlenses.

60. The method of claim 55, wherein the first substrate surface is sloped and is coupled to the first chip surface and the second substrate surface is sloped and is coupled to the second chip surface, and wherein the first and second substrate surfaces are at an angle in the range of about 0.1 to 10 degrees from perpendicular to the optical axis of the optical powers that pass through the optical chip.

61. The method of claim 60, wherein the first block surface is angled and the first spacer includes a first slanted surface and a first back surface opposite the first slanted surface and the second block surface is angled and the second spacer includes a second

slanted surface and a second back surface opposite the second slanted surface, and wherein the first slanted surface is coupled to the first block surface and the first back surface is coupled to the first microlens surface and the second slanted surface is coupled to the second block surface and the second back surface is coupled to the second microlens surface.

62. The method of claim 61, wherein the first spacer includes a first hole such that the optical signals provided by the first plurality of individual optical fibers pass only through air before encountering one of the first plurality of microlenses, and wherein the second spacer includes a second hole such that the optical signals provided to the second plurality of individual optical fibers pass only through air after encountering one of the second plurality of microlenses.

63. The method of claim 55, wherein the first block surface is angled and the first spacer includes a first slanted surface and a first back surface opposite the first slanted surface and the second block surface is angled and the second spacer includes a second slanted surface and a second back surface opposite the second slanted surface, and wherein the first slanted surface is coupled to the first block surface and the first back surface is coupled to the first substrate surface and the second slanted surface is coupled to the second block surface and the second back surface is coupled to the second substrate surface, where the angle of the first and second block surfaces are in a range of about 2 to 20 degrees from perpendicular to the optical axes of the first and second plurality of individual optical fibers, respectively, and where lens axes of the first and second microlenses are tilted to the optical axes that pass through the first and second microlenses at an angle in the range of about 0.1 to 10 degrees.

64. The method of claim 63, where the first spacer includes a first hole such that the optical signals provided by the first plurality of individual optical fibers pass only through air before encountering the first microlens array substrate, and where the second spacer includes a second hole such that the optical signals provided to the second plurality of individual optical fibers pass only through air after encountering the second microlens array substrate.

65. The method of claim 55, wherein the first and second plurality of integrated microlenses are one of graded index (GRIN) lenses, refractive lenses and diffractive lenses.

66. The method of claim 55, further including the steps of:

providing a first index-matched chip spacer for coupling the first microlens array substrate to the optical chip, the first index-matched chip spacer having a refractive index similar to that of the first substrate and including a first inclined surface that is coupled to the first chip surface and a first perpendicular surface opposite the first inclined surface that is coupled to the first microlens array substrate, the first inclined surface having an angle in the range of about 0.1 to 10 degrees from perpendicular to the optical axis of the optical powers that pass through the optical chip; and

providing a second index-matched chip spacer for coupling the second microlens array substrate to the optical chip, the second index-matched chip spacer having a refractive index similar to that of the second substrate and including a second inclined surface that is coupled to the second chip surface and a second perpendicular surface opposite the second inclined surface that is coupled to the second microlens array substrate, the second inclined surface having an angle in the range of about 0.1 to 10 degrees from perpendicular to the optical axis of the optical powers that pass through the optical chip.

67. The method of claim 61, wherein the first spacer is an index-matched spacer that is coupled to the first optical fiber array block and the first microlens array substrate by an index-matched optical adhesive, and wherein the second spacer is an index-matched spacer that is coupled to the second optical fiber array block and the second microlens array substrate by another index-matched optical adhesive.

68. The method of claim 55, wherein the pitch of the first and second plurality of integrated microlenses is about 250 microns.

69. The method of claim 55, wherein the pitch of the first and second plurality of integrated microlenses is within a range of about 125 to 2500 microns.

70. The method of claim 61, wherein the first slanted surface of the first spacer and the first block surface of the first optical fiber array block are in a range of about 2 to 20 degrees from perpendicular to the optical axes of the first plurality of individual optical fibers, and wherein the second slanted surface of the second spacer and the second block surface of the second optical fiber array block are in a range of about 2 to 20 degrees from perpendicular to the optical axes of the second plurality of individual optical fibers.

71. The method of claim 55, wherein the optical chip includes at least one of an optical isolator chip, an optical circulator chip, a gain flattening filter, a thin film filter, a variable optical attenuator, a polarization beam splitter, a wavelength plate, a prism, a grating, a mirror, a dynamically adjustable active optical material and a polarizing material.

72. The method of claim 71, wherein the optical isolator chip is a stacked optical isolator chip that includes first and second birefringent crystal plates, a half-wave plate and one of a latching garnet and a non-latching garnet.

73. An optical system, comprising:

an arrayed in-line optical device, including:

a first optical fiber collimator array having a first optical fiber array block and a first microlens array substrate, wherein the first optical fiber array block includes a first block surface and is configured to receive and retain a first plurality of individual optical fibers which carry optical signals, and wherein the first microlens array substrate is coupled to the first optical fiber array

block and includes a first plurality of microlenses integrated along a first microlens surface and a first substrate surface opposite the first microlens surface, where the optical signals from the first plurality of individual optical fibers are each collimated by a different one of the first plurality of integrated microlenses;

a second optical fiber collimator array having a second optical fiber array block and a second microlens array substrate, wherein the second optical fiber array block includes a second block surface and is configured to receive and retain a second plurality of individual optical fibers which carry the optical signals, and wherein the second microlens array substrate is coupled to the second optical fiber array block and includes a second plurality of microlenses integrated along a second microlens surface and a second substrate surface opposite the second microlens surface, where the optical signals provided to the second plurality of individual optical fibers are each provided by a different one of the second plurality of integrated microlenses; and

an optical chip coupled between the first microlens array substrate and the second microlens array substrate, the optical chip including a first chip surface and a second chip surface;

a light source module coupled to at least one of the first plurality of individual optical fibers, the light source module providing the optical signals to the first plurality of individual optical fibers; and

a light receiver module coupled to at least one of the second plurality of individual optical fibers, the light receiver module receiving the optical signals from the second plurality of individual optical fibers.

74. The system of claim 73, further including:

an optical amplifier for amplifying the optical signals, wherein the optical amplifier is coupled between one of the light source module and the arrayed optical device and the arrayed optical device and the light receiver module.

75. The system of claim 73, further including:

a dispersion compensation module for controlling the chromatic dispersion of the optical signals, wherein the dispersion compensation module is coupled between one of the light source module and the arrayed optical device and the arrayed optical device and the light receiver module.

76. The system of claim 73, further including:

a polarization compensation module for controlling the polarization dispersion of the optical signals, wherein the polarization compensation module is coupled between one of the light source module and the arrayed optical device and the arrayed optical device and the light receiver module.

77. An optical system, comprising:

an arrayed in-line optical device, including:

a first optical fiber collimator array having a first optical fiber array block and a first microlens array substrate, wherein the first optical fiber array block includes a first block surface and is configured to receive and retain a first plurality of individual optical fibers which carry optical signals, and wherein the first microlens array substrate is coupled to the first optical fiber array block and includes a first plurality of microlenses integrated along a first microlens surface and a first substrate surface opposite the first microlens surface, where the optical signals from the first plurality of individual optical fibers are each collimated by a different one of the first plurality of integrated microlenses;

a second optical fiber collimator array having a second optical fiber array block and a second microlens array substrate, wherein the second optical fiber array block includes a second block surface and is configured to receive and retain a second plurality of individual optical fibers which carry the optical signals, and wherein the second microlens array substrate is coupled to the second optical fiber array block and includes a second plurality of microlenses integrated along a second microlens surface and a second substrate surface opposite the second microlens surface, where the optical signals provided to the second plurality of individual optical fibers are each provided by a different one of the second plurality of integrated microlenses;

an optical chip coupled between the first microlens array substrate and the second microlens array substrate, the optical chip including a first chip surface and a second chip surface; and

at least one of an optical in-line device and an optical waveguide, wherein one of the optical in-line device and the optical waveguide is coupled between one of the second plurality of individual optical fibers and one of the first plurality of individual optical fibers.

78. The system of claim 77, wherein the optical waveguide is an optical amplifier fiber.

79. The system of claim 77, wherein the optical in-line device is a dispersion compensation module for controlling the chromatic dispersion of the optical signals.

80. The system of claim 77, wherein the optical in-line device is a polarization compensation module for controlling the polarization dependence of the optical signal.